Periodic Table of Elements

The Search for Order and Organization

Organizing

- How do you organize your CD collection?
- How are DVDs organized on those Red Box machines?
- How are books organized in a library?

Organizing

- How do you organize your CD collection?
- How are DVDs organized at BlockBluster?
- How are books organized in a library?

WHY DO WE ORGANIZE THINGS ANYWAY?

Organizing

- How do you organize your CD collection
- How are DVDs organized at BlockBuster?
  - **Organized by "theme"**
- How are books organized in a library?
  - **Organized by "theme"**

WHY DO WE ORGANIZE THINGS ANYWAY?

- ANS: To make things easier to find and to be able to group things according to trends.

Organizing

- **The placement of elements on the modern periodic table reveals patterns:**
  - **The atomic structure of atoms (number of protons, neutrons, electrons, and energy levels)**
  - **The properties of each element.**

Modern-day Periodic Table

Today, there are 115 known elements (115 different combinations of protons – some natural and some man-made).

- A few are known to exist, but:
- have not yet been discovered OR
- are too unstable to study.

Many of these elements have only recently been discovered or created in a lab…

Better Science = More elements Discovered

Up until 1750s, there were only 17 known elements…

But as these elements were put in systematic (orderly) groupings, scientists began to discover more elements.

Attempt #1: Antoine Lavoisier (1700s)

- <u>Activity</u>: Organizing a bag of stuff – How would you put these objects in order??

Organizing Periodic Table Attempt #1: Antoine Lavoisier (1700s)

- He was a French chemist who grouped the known elements into 4 categories.
- These groupings were **based on:**
- **substances with similar characteristics** that could not be broken down any smaller with the technology of the 1700s

Attempt #1: 1700s

Antoine Lavoisier's four categories were:

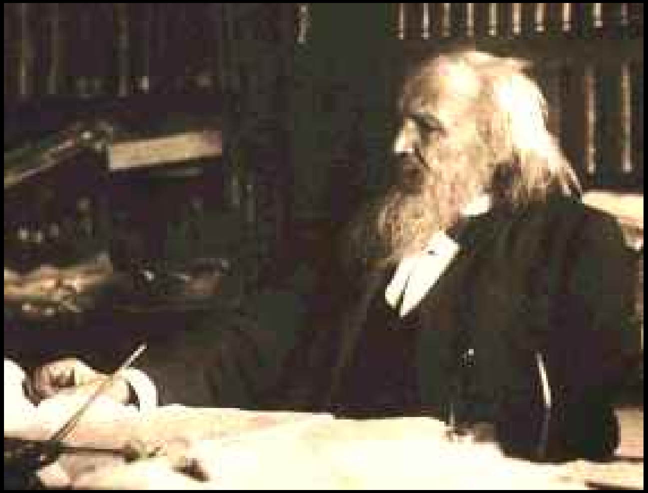
1. **metals** → metallic materials
2. **nonmetals** → not metallic
3. **gases** → those belonging to all living things in nature
4. **and earths** → elements that looked like rock/dirt

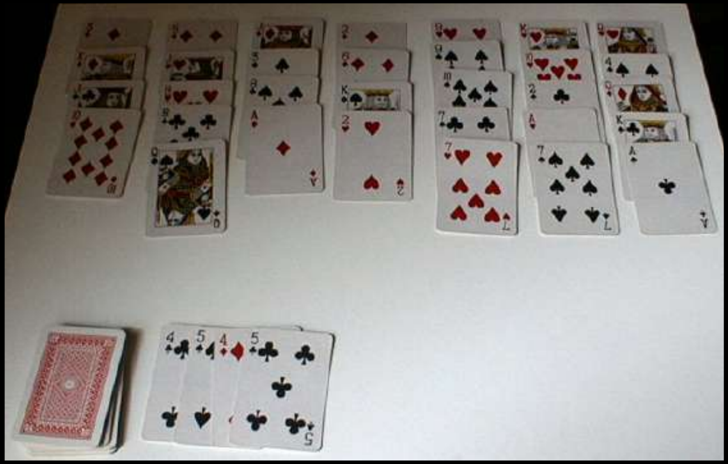
Attempt #1: 1700s

However, these groupings did not always work and some elements fell into more than one category…

Think of your way of categorizing music on your ipods…music you consider “modern rock” may be considered “alternative” by someone else

Attempt #2: Mendeleev’s Periodic Table





- Russian Chemist and Science Teacher in the 1860s.
- Was writing a chemistry book and was trying to figure out how to organize the known elements.
- He came up with a solution based on the game solitaire.

How To Play Solitaire

- In certain versions of Solitaire, the player tries to sort a deck of cards by suit (hearts, diamonds, etc.) and value.
- Mendeleev tried to do the same thing for the elements…he made a “deck of cards” out of the elements

Mendeleev’s Organized Table

Characteristics used by Mendeleev:

- Mendeleev put the elements in rows by increasing atomic masses.

- He started a new row every time chemical properties repeated themselves.

1	2	3	4	5	6	7
8	9		11	12	13	14
	16		18	19	20	21
22	23	24	25		27	
29		31	32	33		35
36	37	38			41	42

Mendeleev's Finishing Touches

Characteristics used by Mendeleev:

- This produced columns with similar properties. If there seemed to be a missing element, he left a gap in the table.

1	2	3	4	5	6	7
8	9		11	12	13	14
	16		18	19	20	21
22	23	24	25		27	
29		31	32	33		35
36	37	38			41	42

Mendeleev's Finishing Touches

- **Notice that this left blank spots in the grid of elements.**

1	2	3	4	5	6	7
8	9		11	12	13	14
	16		18	19	20	21
22	23	24	25		27	
29		31	32	33		35
36	37	38			41	42

Able to make predictions about the unknown elements due to placement.

Final Results: Mendeleev's Periodic Table

Reihen	Gruppe I.	Gruppe II.	Gruppe III.	Gruppe IV.	Gruppe V.	Gruppe VI.	Gruppe VII.	Gruppe VIII.
	—	—	—	RH^4	RH^3	RH^2	RH	—
	R^2O	RO	R^2O^3	RO^2	R^2O^5	RO^3	R^2H^7	RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 53)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	S = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 198)	Hg = 200	Tl = 204	Pb = 207	Bi = 208			
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Final Results: Notice the blank spots on the element table.

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2H^7	Gruppe VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9, 4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27, 3	Si = 28	P = 31	S = 32	Cl = 35, 5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 198)	Hg = 200	Tl = 204	Pb = 207	Bi = 208			
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Mendeleev's Periodic Table had columns with the same properties and the masses of each element increasing as you went down the column. He left blank spaces for unknown elements

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2H^7	Gruppe VIII. — RO^4
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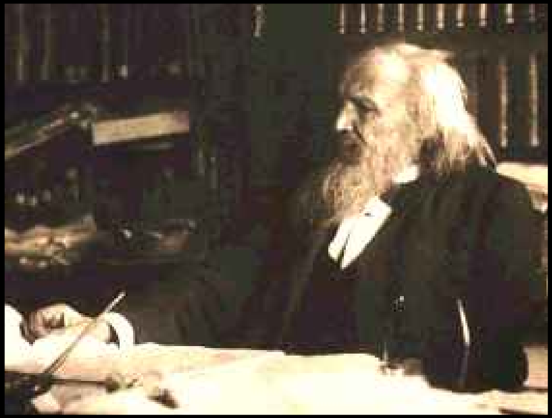
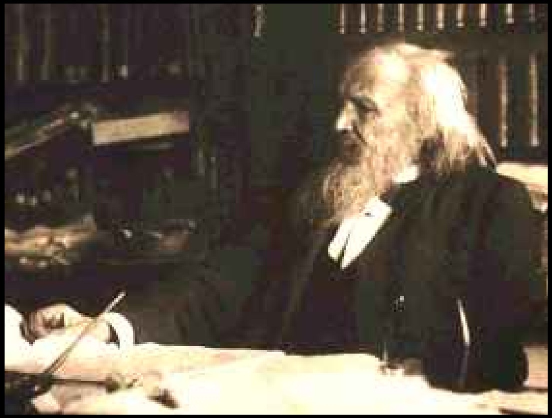


BIG IDEA: Why was Mendeleev's Periodic Table so Important?

1. Mendeleev left blanks in his table for unknown elements that would complete the properties pattern but not yet discovered.
2. This reinforced the idea that an element's location on the periodic table was related to its properties. No longer did students need to memorize the properties of all elements…just become familiar with one or two in a column and the rest would be similar.



BIG IDEA: Why was Mendeleev's Periodic Table so Important?

3. The table worked SO WELL, that Mendeleev was able to make predictions about the unknown elements by looking at the surrounding known elements.

Did these predictions work?

- Mendeleev used his table to predict the existence of a metal that would lay below aluminum in the table.
- He hypothesized that the metal would be extremely soft with a VERY LOW melting point.
- In 1985, the metal Gallium was discovered. This metal had the mass and characteristics predicted by Mendeleev.

What Mendeleev Didn’t Know

- Mendeleev did not know that every atom of the same element has the <u>SAME</u> number of protons…
- The “atomic masses” he used on his periodic table were <u>NOT</u> really the masses of individual atoms (the technology did not exist to measure atoms).
- Instead, the masses were determined through experiments and were measuring a larger amount of material.

What Mendeleev Didn’t Know

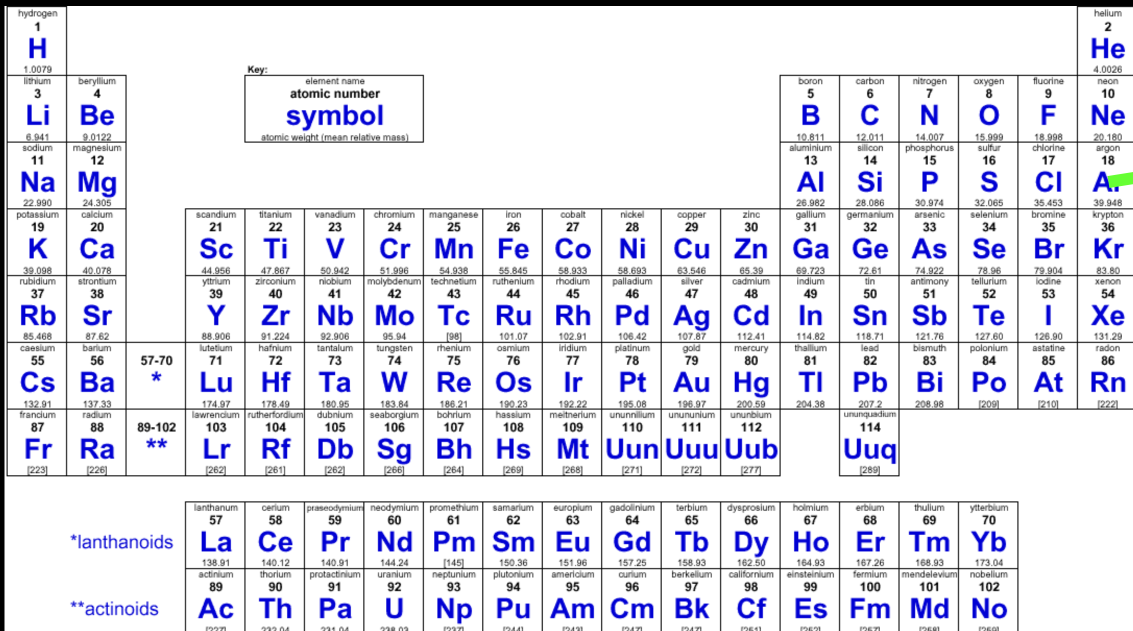
- Remember, Mendeleev organized the elements into rows based on increasing atomic masses.
- The problem → Mendeleev found that some elements did not quite fit the pattern of similar characteristics when organized by increasing atomic masses.

Attempt #3: Henry Moseley

- Henry Moseley shot x-rays at the known elements and was able to determine the number of protons found in each element's atoms.

- Moseley arranged elements by increasing atomic number (number of protons) which fixed many of the discrepancies (problems) with Mendeleev's table.

Looking at the Modern Periodic Table

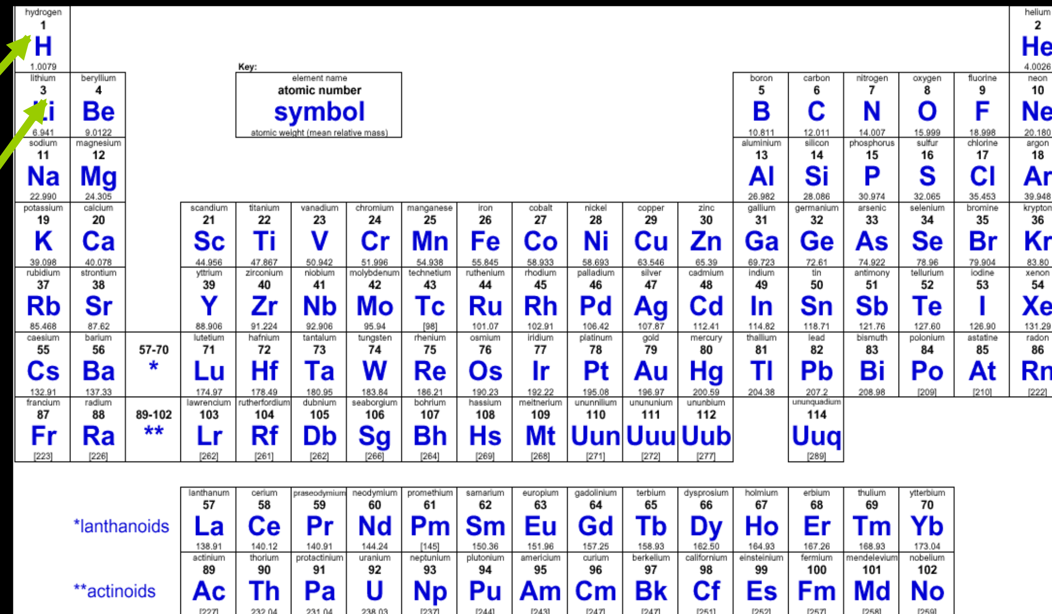


The element with the next atomic number has characteristics that match the first column.

<u>Principal of Periodic Law:</u> The modern periodic table organizes elements by atomic number, groups (columns) of elements have same characteristics.

Organizing the Modern Periodic Table

Energy Levels, Orbitals, Electrons		
Energy Level (PERIOD)	Number of Orbitals	Maximum # of electrons
1	1	2
2	4	8



- Each row in the Periodic Table is called a "**period**" and tells you the number of energy levels for the first three rows.

Organizing the Modern Periodic Table

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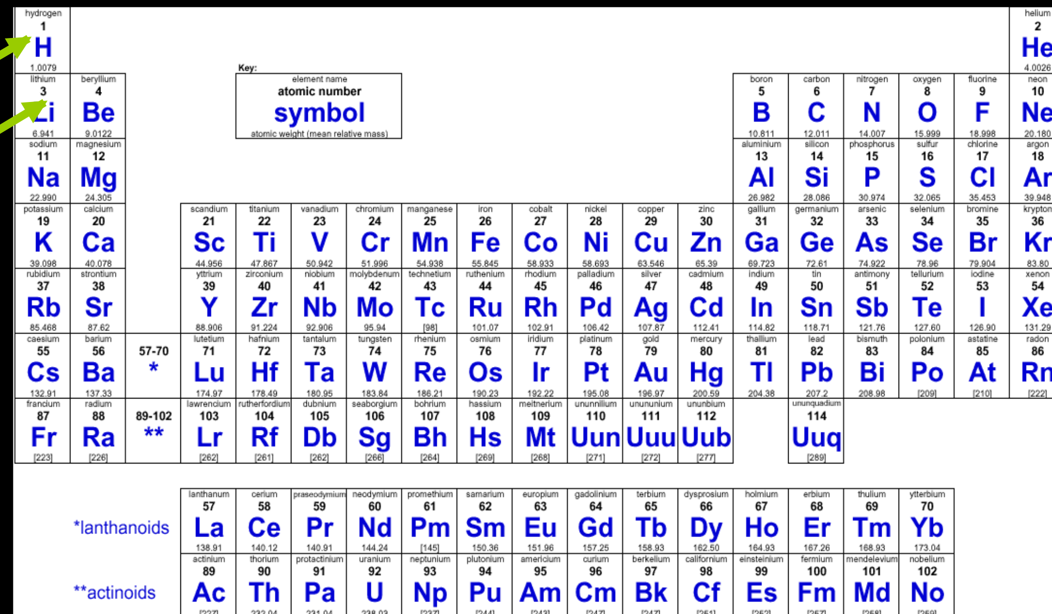
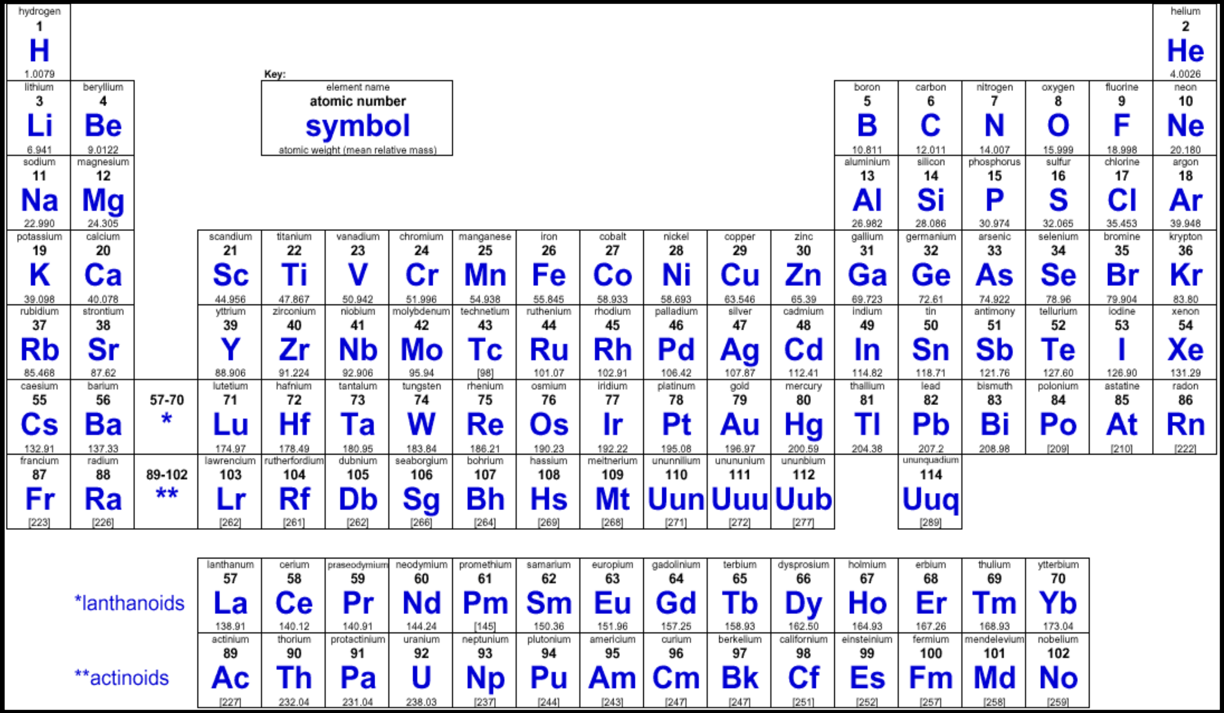


- **The first element in EACH period has all prior energy levels completely filled and ONE electron in the new energy level.**
- EX: Sodium is in Period 3, so Energy Levels 1&2 are filled, with ONE electron in the 3rd Energy Level.

Looking at the Periodic Table

- **Each column in the periodic table is called a "<u>group</u>" and the group number tells you the number of valence electrons in each atom.**

- **Each group has a specific set of "properties".**



Organizing the Modern Periodic Table

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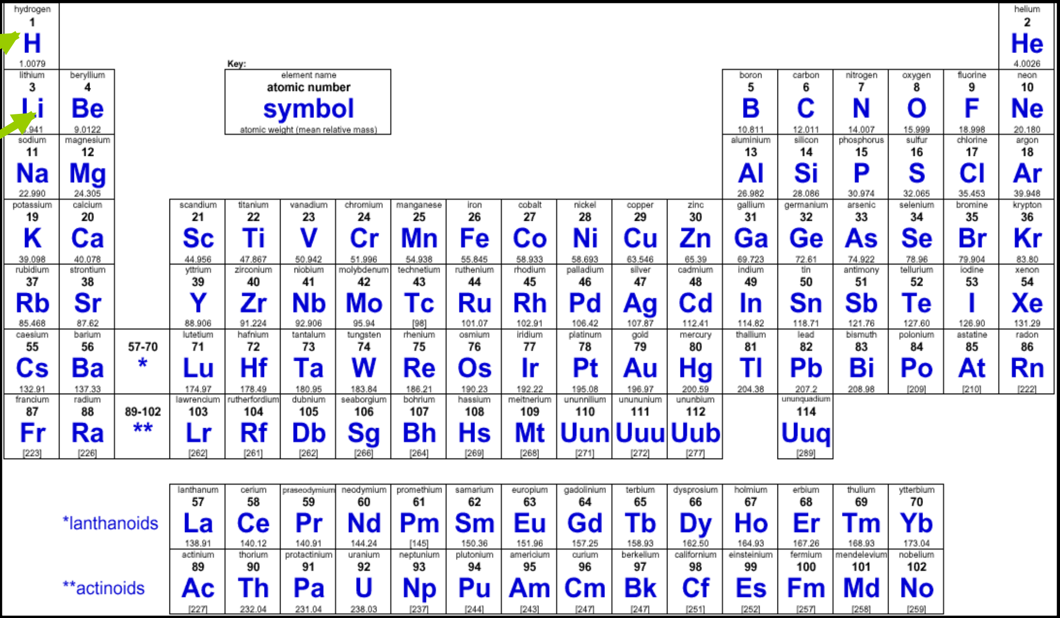
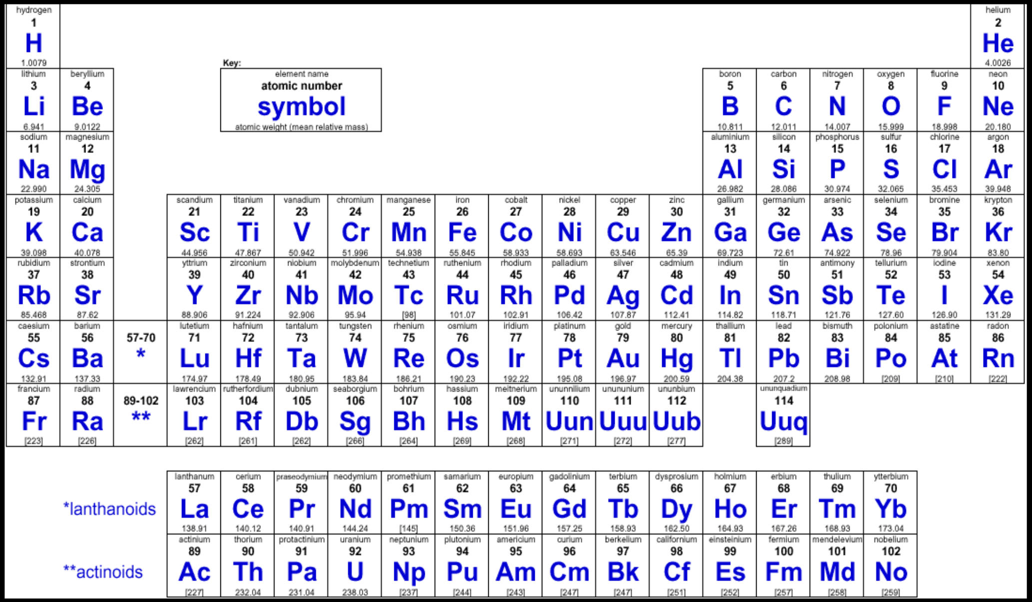


- **The first element in EACH period has all prior energy levels completely filled and ONE electron in the new energy level.**

- The group number tells you the number of electrons in the outer most energy level. These are called the "valence electrons"

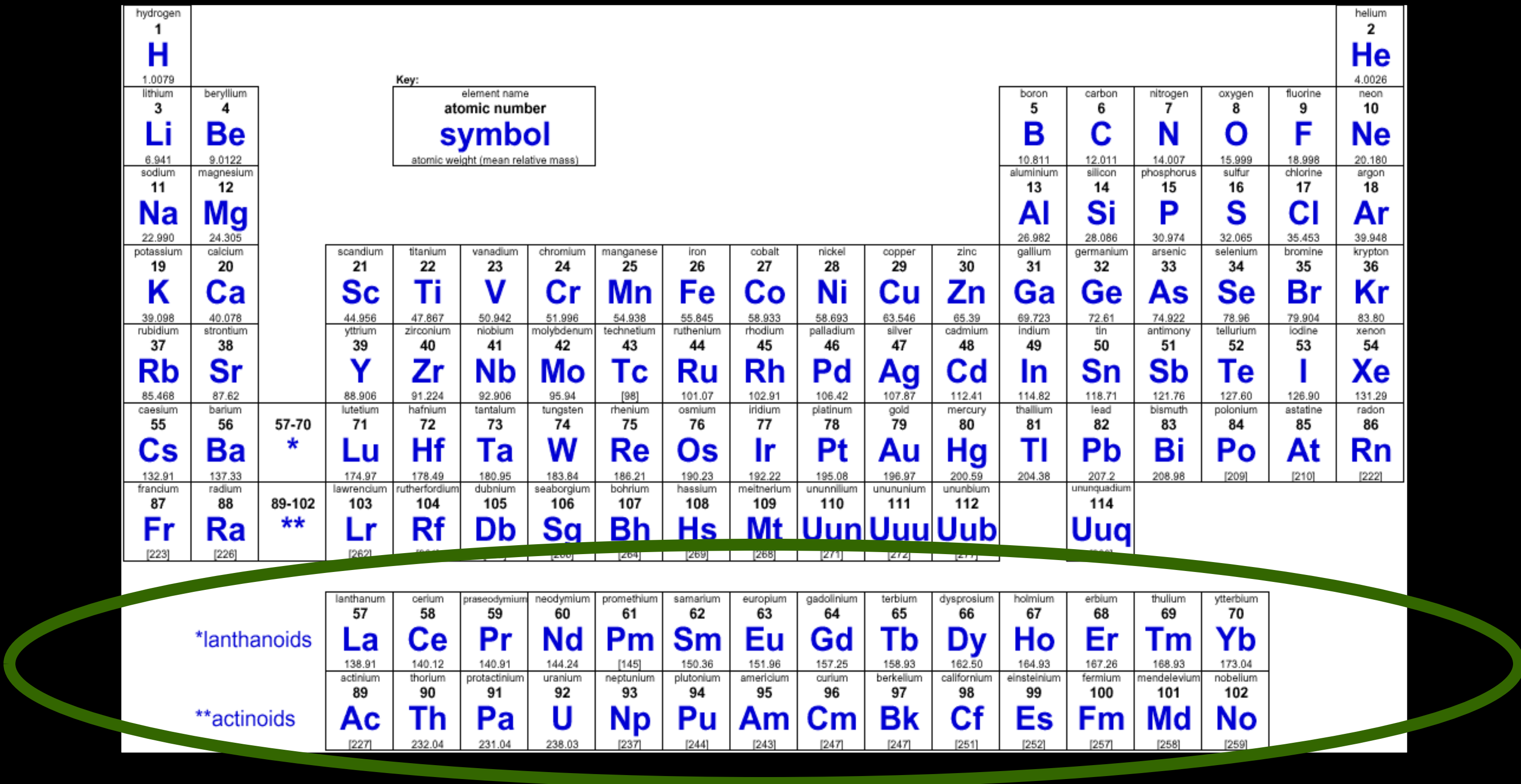
Looking at the Periodic Table

- **Each column in the periodic table is called a "group"**
- **Each group has a specific set of "properties"**



- **The elements in each "group"** have similar properties because they have the same number of outer or valence electrons.
- The group number will tell you how many valence electrons elements in that group or column have.

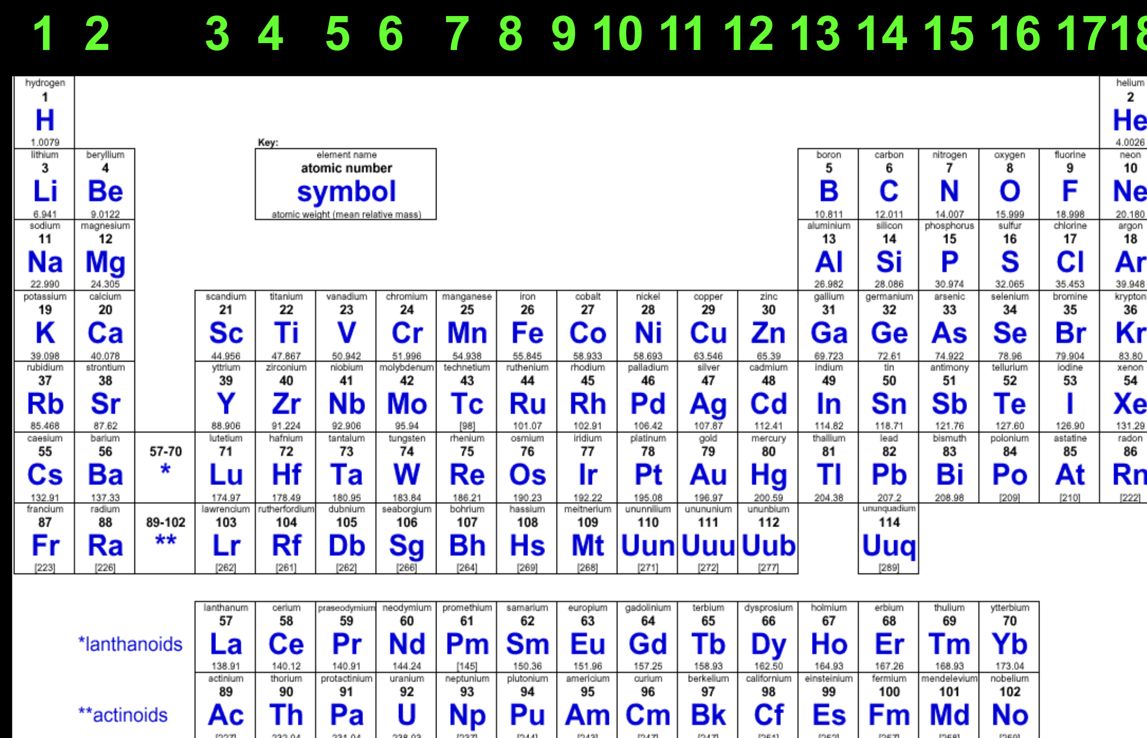
Looking at the Periodic Table



- Elements from Periods 6 and 7 are broken up and placed at the bottom of the page to make the periodic table more compact. (These energy levels contain a LARGE number of orbitals).

Lewis Dot Structure

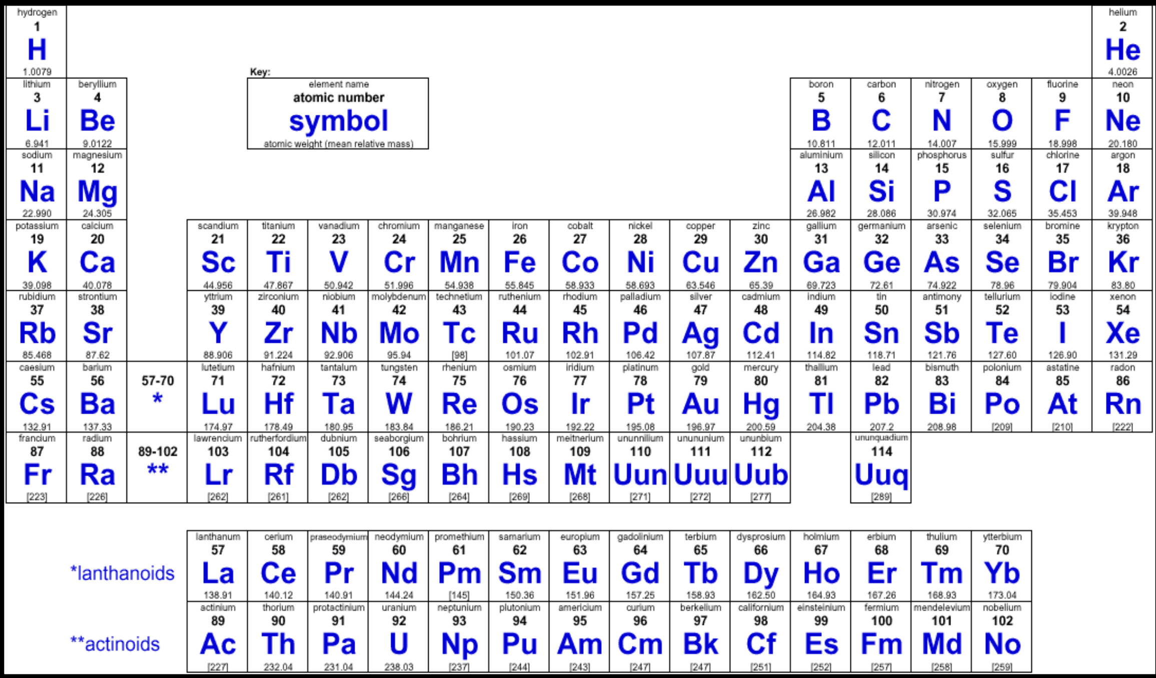
- We will see in future lessons that the reactivity of an element is MOSTLY dependent on how many electrons are in an atom's outer (highest) energy level.



Lewis Dot Structure

•Remember, the number of electrons in the outer energy level is indicated by the group the element is found in.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1718



Lewis Dot Structure

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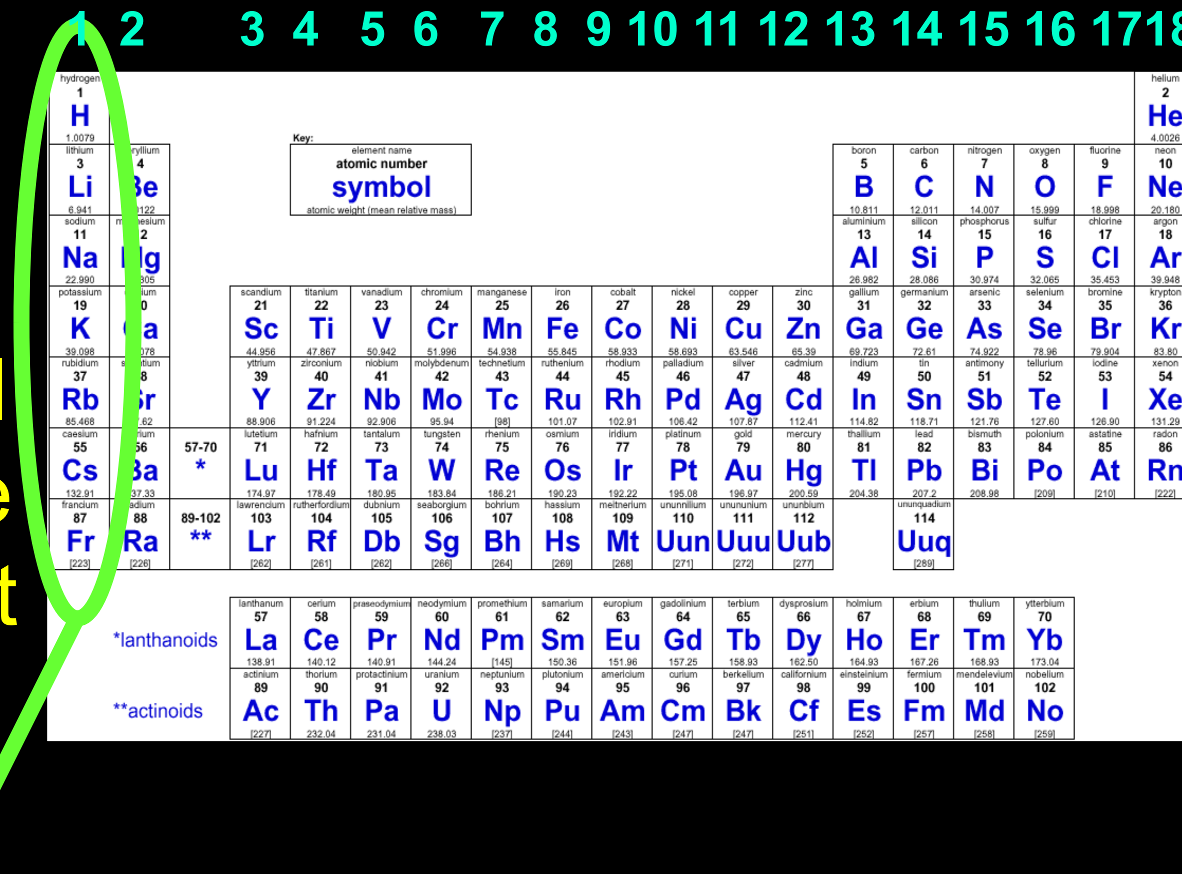
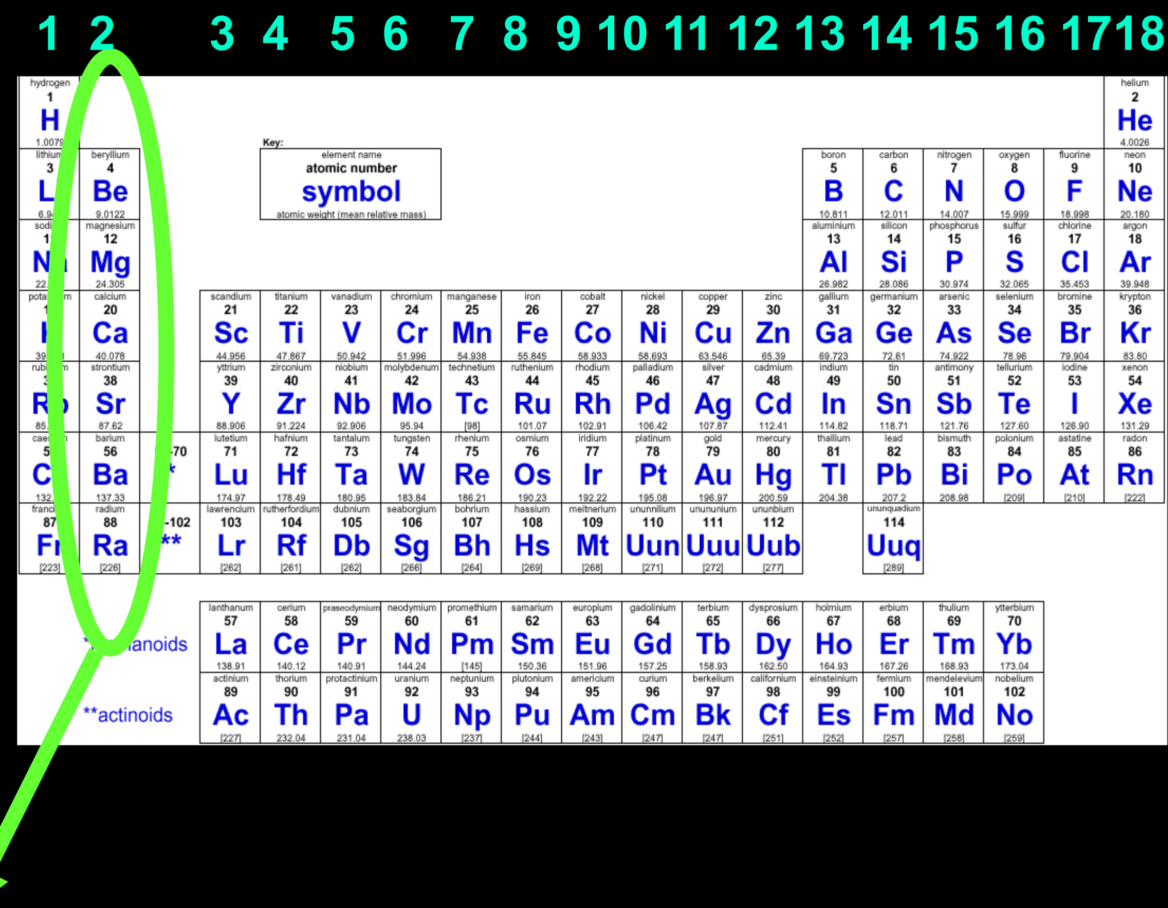


<u>Group 1</u>: One electron in outer energy level

Lewis Dot Structure

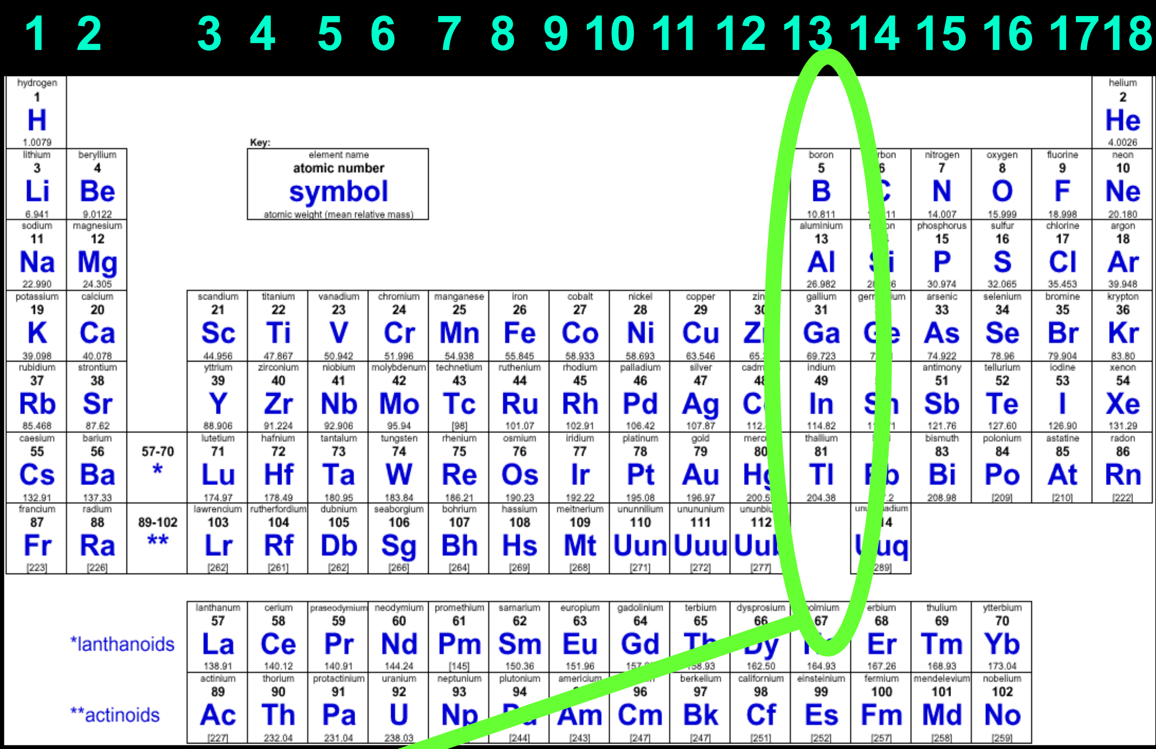
- Remember, the number of electrons in the outer energy level is indicated by the group the element is found in.



<u>Group 2</u>: Two electron in outer energy level

Lewis Dot Structure

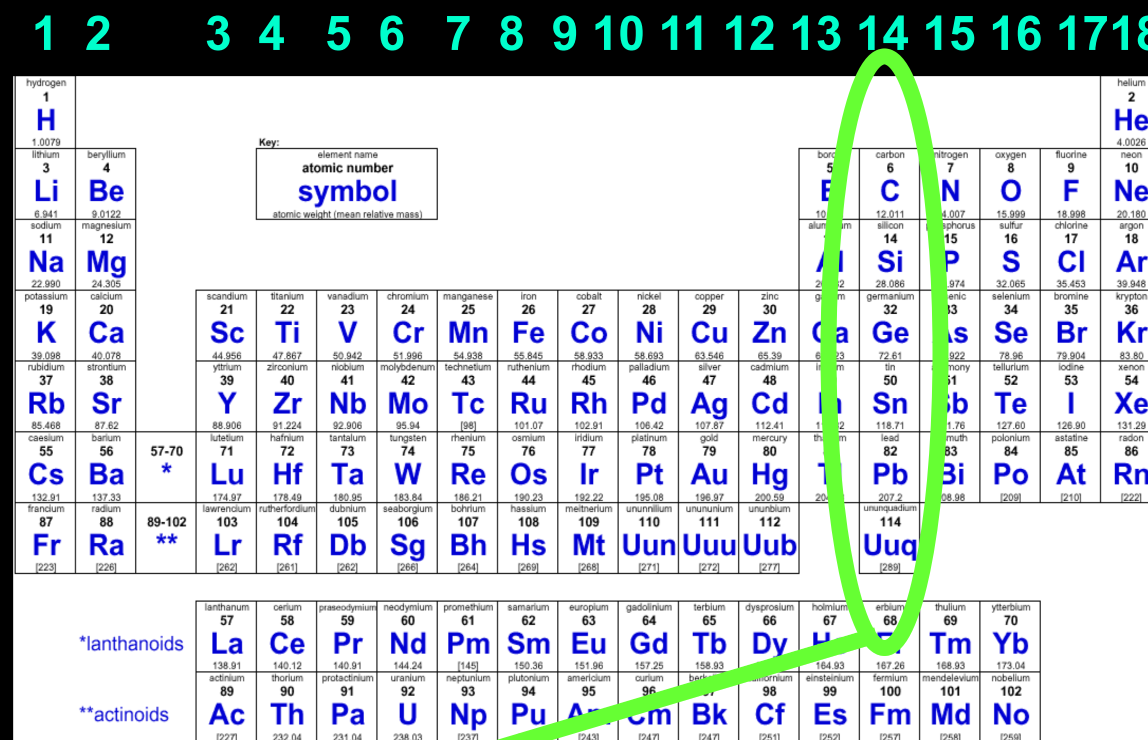
- Remember, the number of electrons in the outer energy level is indicated by the group the element is found in.



<u>Group 13</u>: Three electron in outer energy level…to remember how many electrons, just cross out the "1" in the group number

Lewis Dot Structure

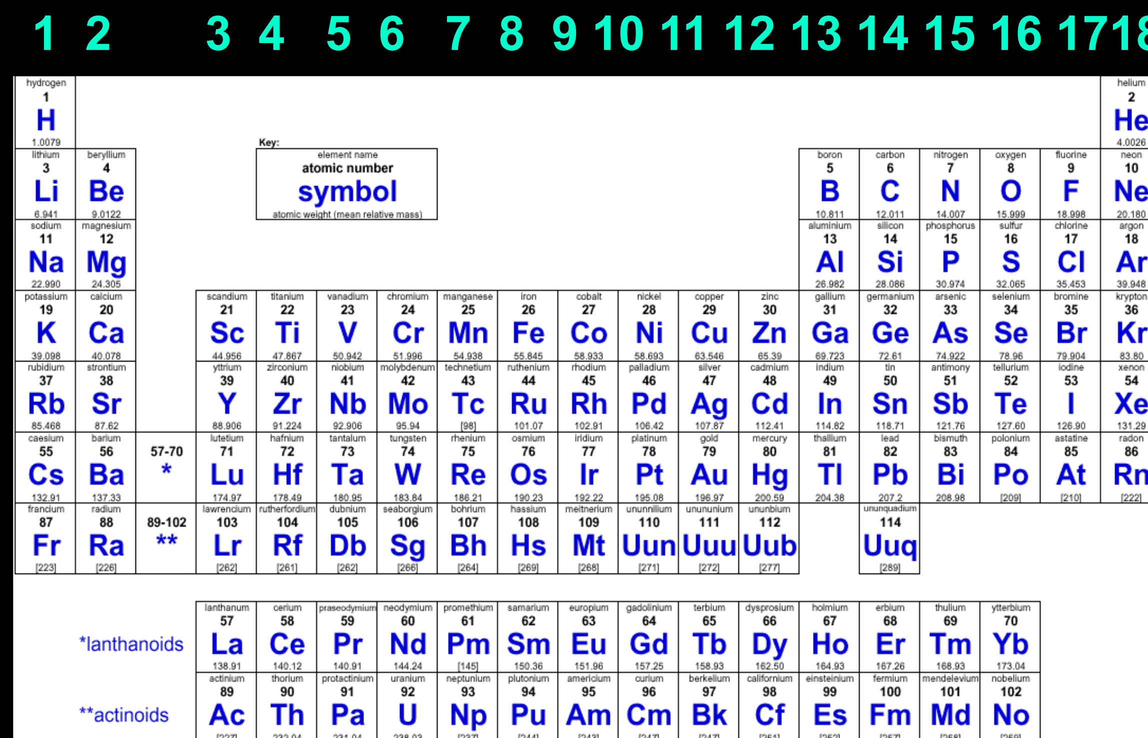
- Remember, the number of electrons in the outer energy level is indicated by the group the element is found in.



<u>Group 14</u>: Four electron in outer energy level…to remember how many electrons, just cross out the "1" in the group number

Lewis Dot Structure

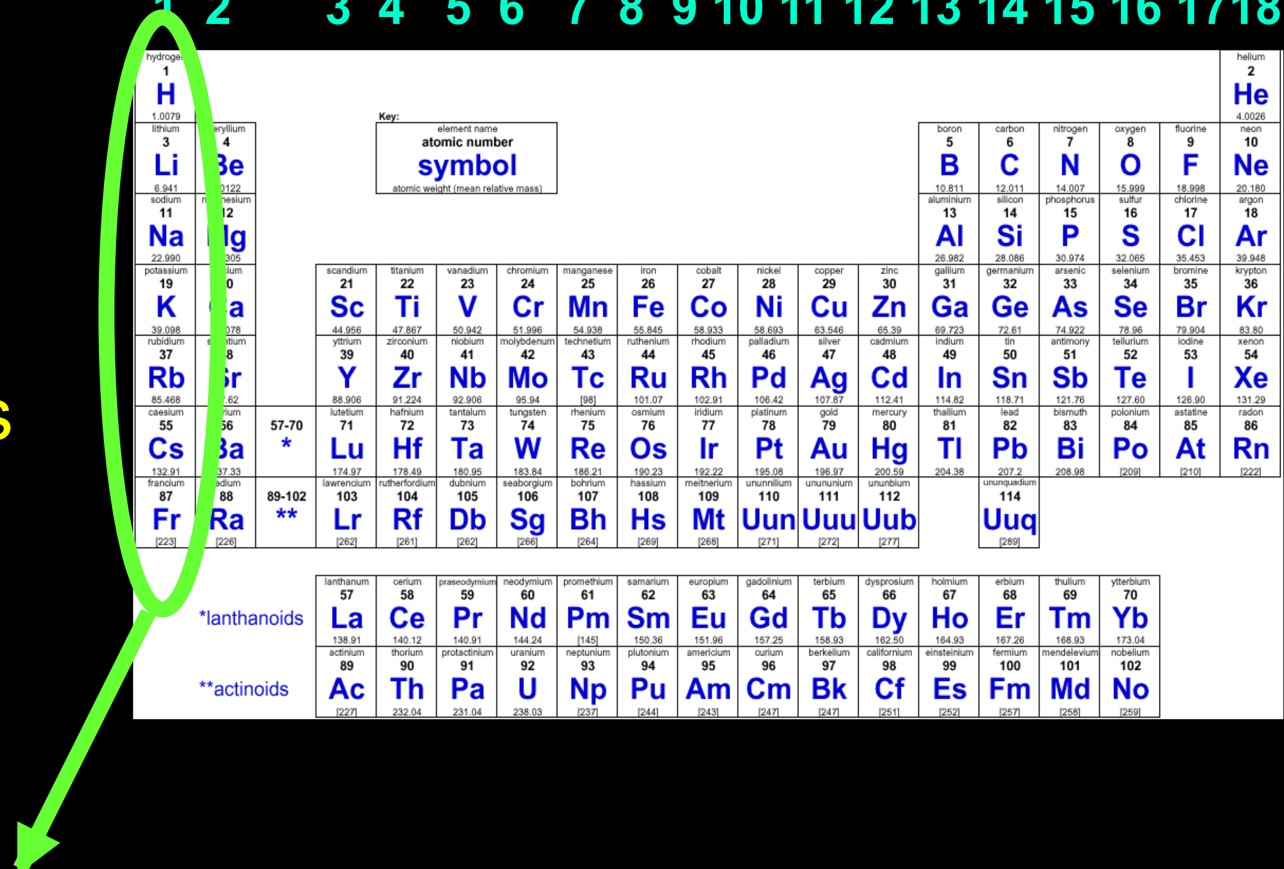
- Since we really only care about how many electrons an atom has in the outer energy level, we use what is called a Lewis Dot Structure.



<u>**Lewis Dot Structure**</u>: A method to indicate how many valence electrons an atom has. This method is commonly used for Groups 1,2,13-18

Lewis Dot Structure

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

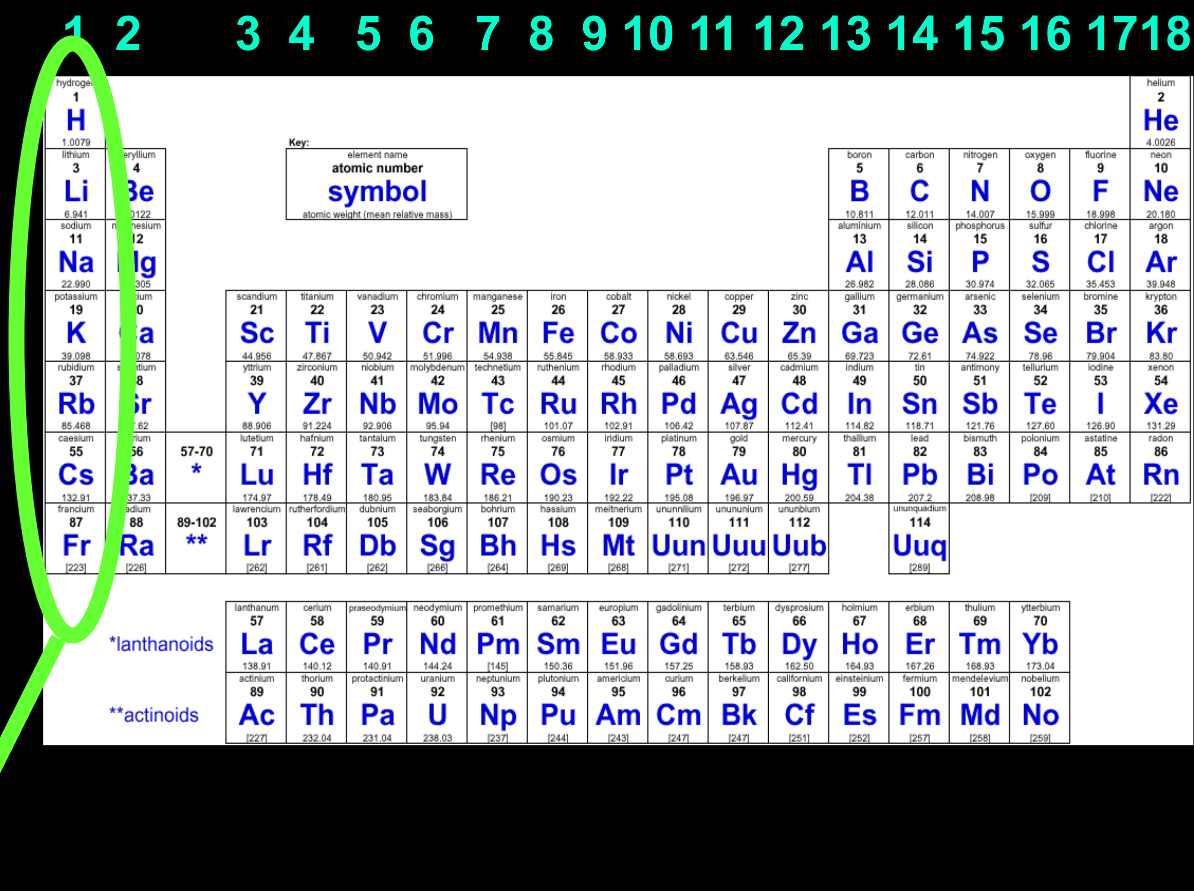


- **<u>Lewis Dot Structure</u>**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.

<u>Example</u>: Sodium (Na) is in Group 1, so the Lewis Dot Structure would be: Na with a single dot to represent "1" electron in the outer energy level.

Lewis Dot Structure

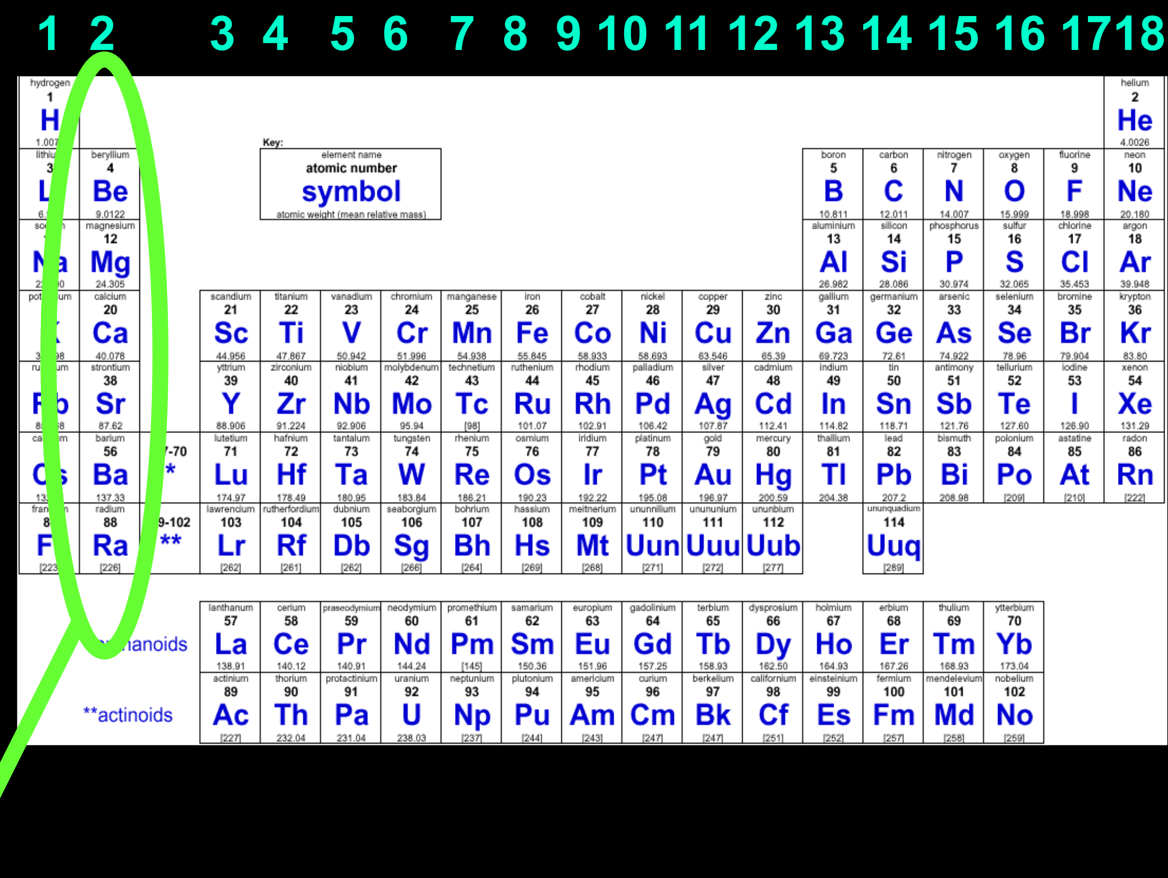
- **Lewis Dot Structure**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.



Example: Na •

Lewis Dot Structure

- **<u>Lewis Dot Structure</u>**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.

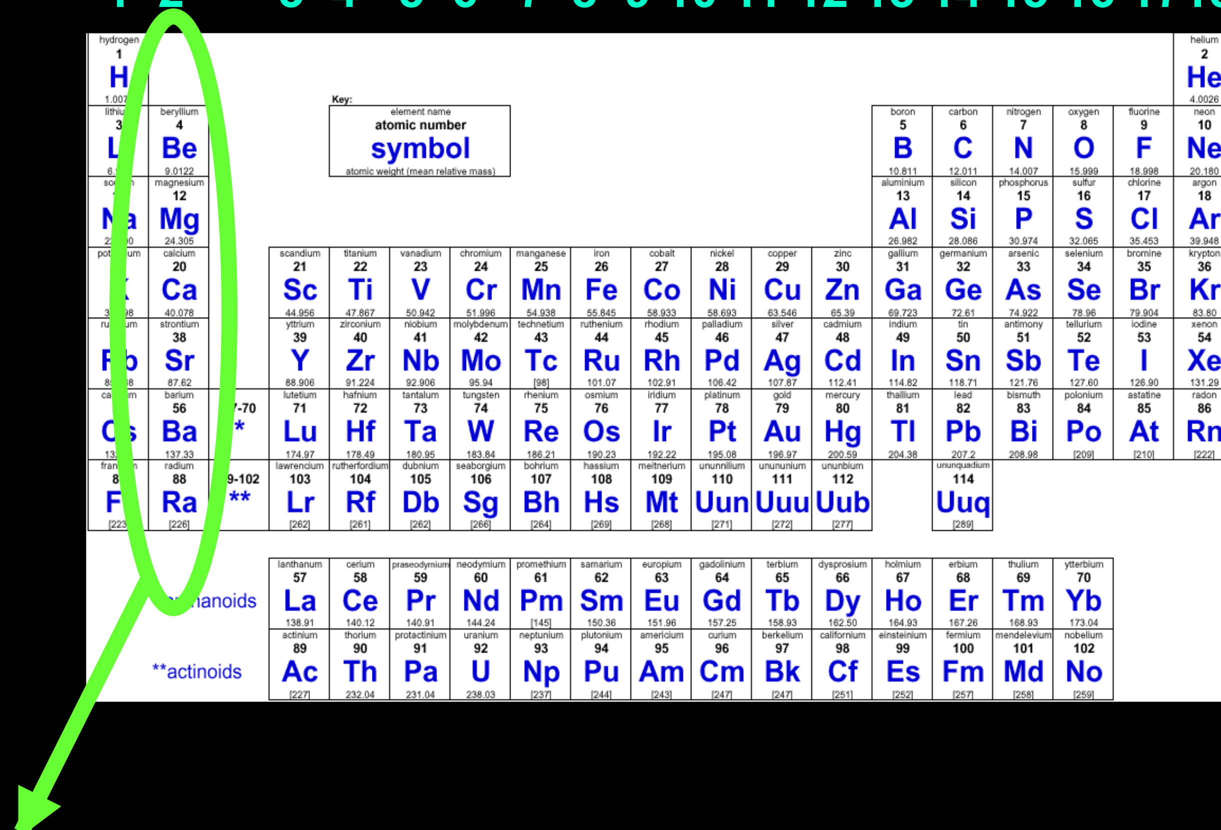


<u>Example</u>: Calcium (Ca) is in Group 2, so the Lewis Dot Structure would be: Ca with two dots to represent "2" electrons in the outer energy level.

Lewis Dot Structure

- **<u>Lewis Dot Structure</u>**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.

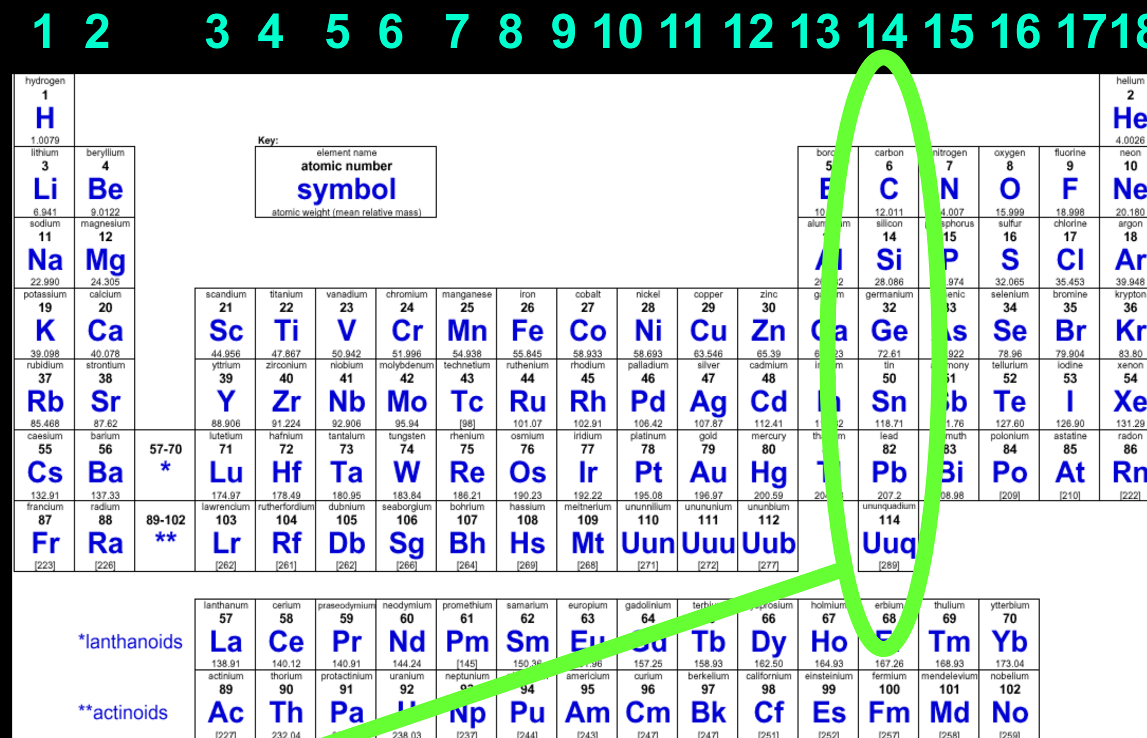
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18



<u>Example:</u> **Ca :**

Lewis Dot Structure

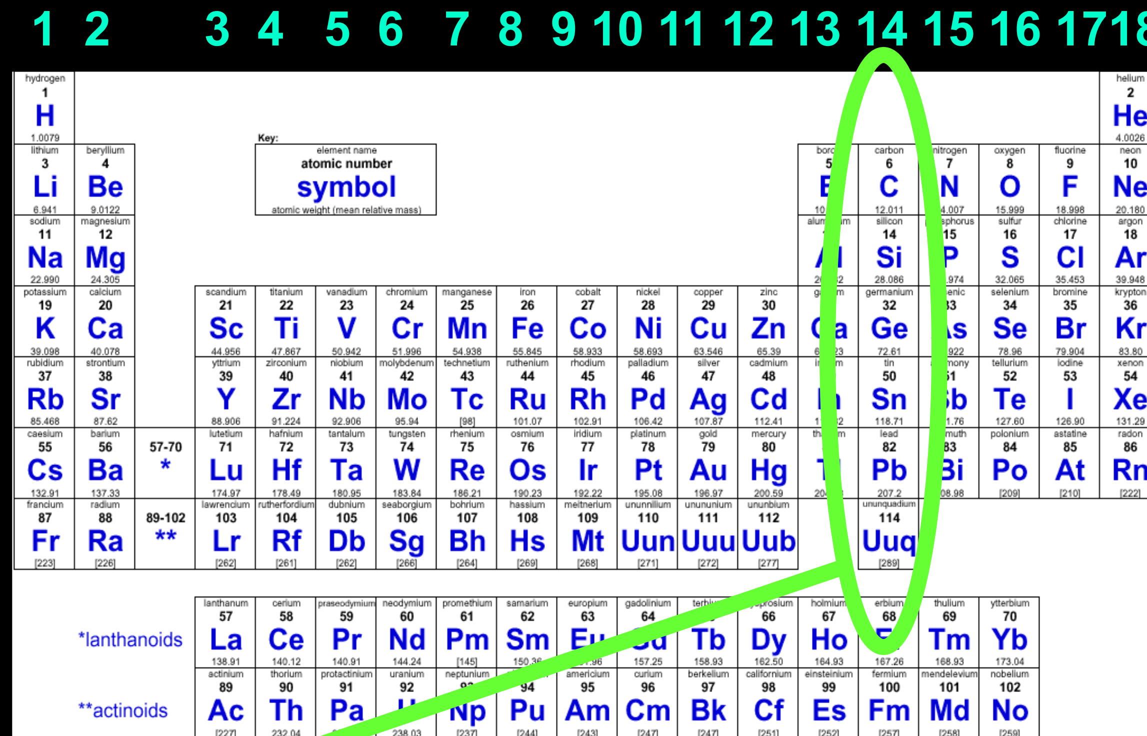
- **Lewis Dot Structure**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.



Example: Carbon (C) is in Group 14, so the Lewis Dot Structure would be: C with four dots to represent "4" electrons in the outer energy level.

Lewis Dot Structure

- **Lewis Dot Structure**: Write the element's symbol and then an amount of dots equal to the electrons in the outer energy level.



Example: .C:

Lewis Dot Structure

- Why are there only 8 possible Lewis Dot Structure Patterns?

Lewis Dot Structure

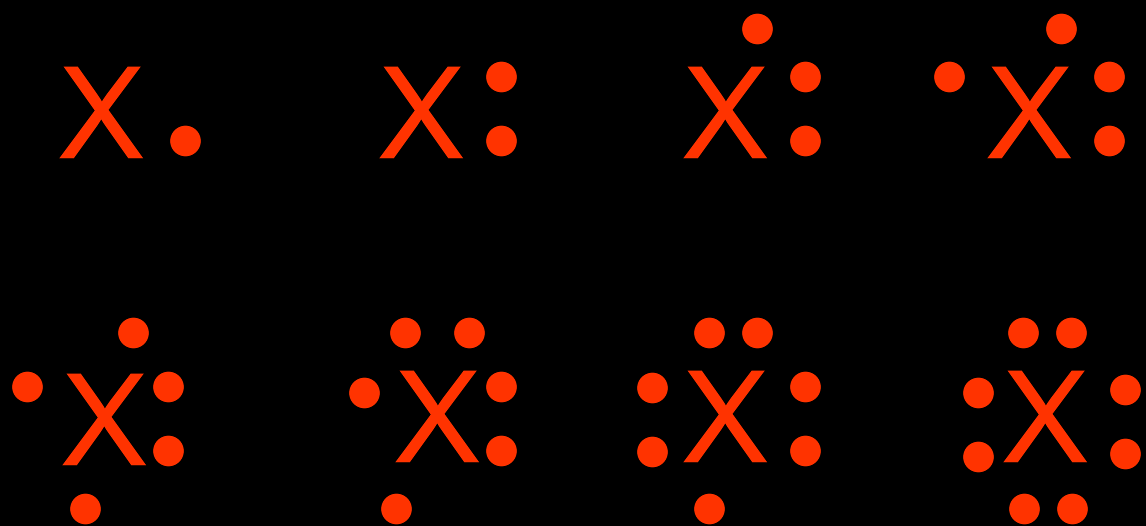
- Why are there only 8 possible Lewis Dot Structure Patterns?
- ANS: Because the atoms that we are concerned with want to have 8 electrons in their outer energy level.
  - Except for energy level one which holds 2 electrons

Perfection!

- Are there any atoms that already have a perfect number of valence electrons?
- YES! → Group 18

Rules for Writing Lewis Dot Structures

Please note that you can place the first two dots on any side, but the rest of the dots should be placed in either a clockwise or counter clockwise manner, with **<u>no side</u>** receiving two dots until each side gets one.

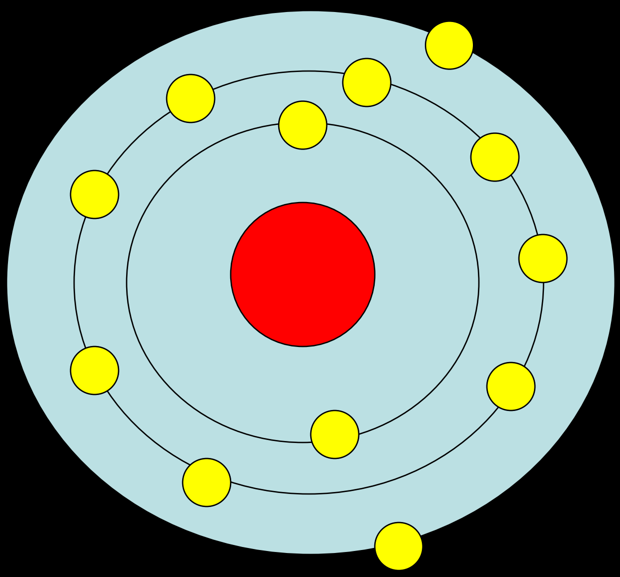


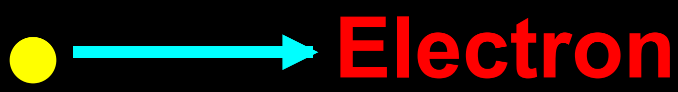
Why Lewis Dot Structure is important Ions

- Ions are atoms that have either LOST or gained electrons to have a full outer energy level.→ no longer neutral. → Already played the game!
- End with either 8 electrons by gaining new electrons or losing 1 or 2 electrons in the outside energy level so it disappears revealing a full inner energy level.
- Na^+ → sodium lost one electron so it is positive.
- Mg^{2+} → lost two electrons so it is positive.
- Cl^- → gained one electron so it is negative

Satisfying the Valence

- Draw the diagram

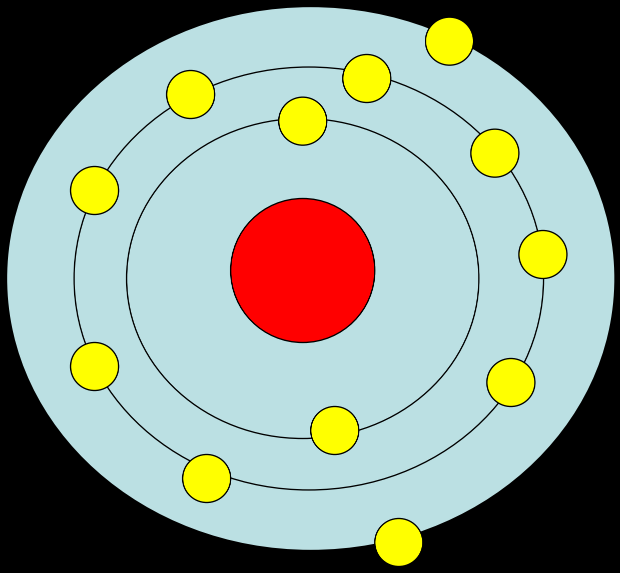




How many energy levels are there?

How many valence electrons are there?

Satisfying the Valence

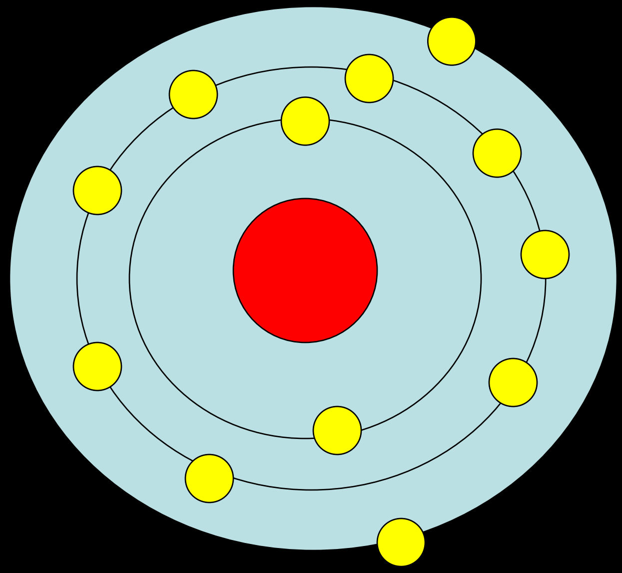


How many energy levels are there? 3

How many valence electrons are there? 2

Satisfying the Valence

Electron

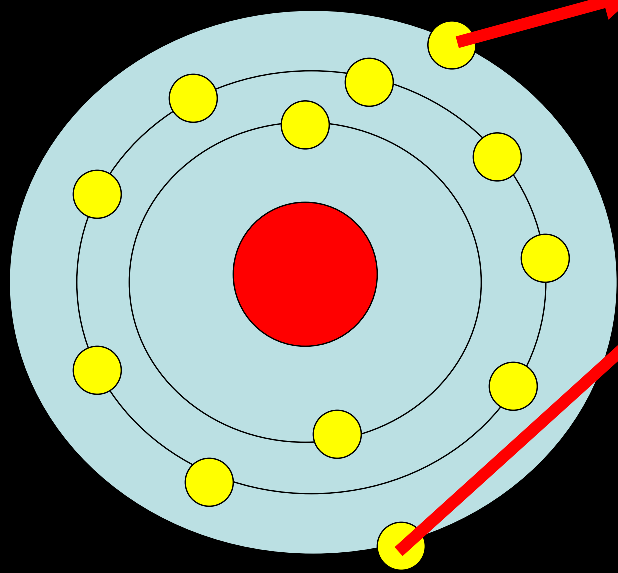


- THE BIG RULE: most atoms are happiest when they have a FULL outer energy level (typically 8)
- If there are only 1 or 2 electrons in the outer energy level than the atom wants to LOSE the extra electrons.

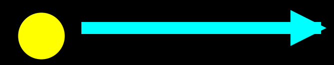
Satisfying the Valence

Electron

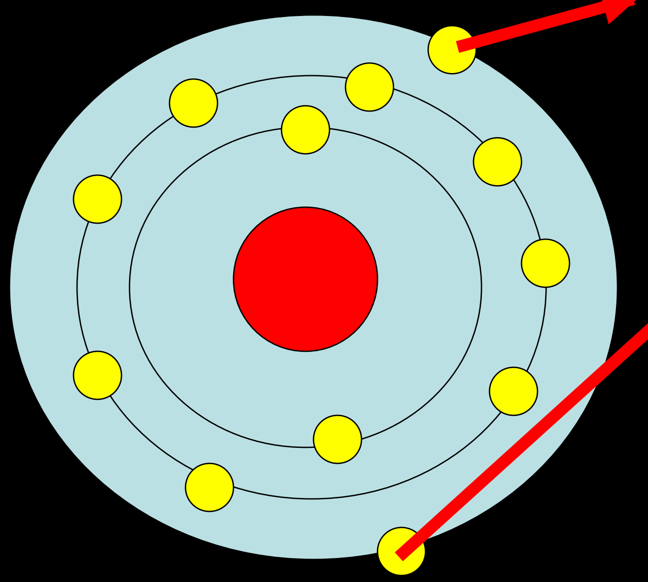
Example: this atom has 2 valence electrons.



Satisfying the Valence


Electron

Example: this atom has 2 valence electrons.

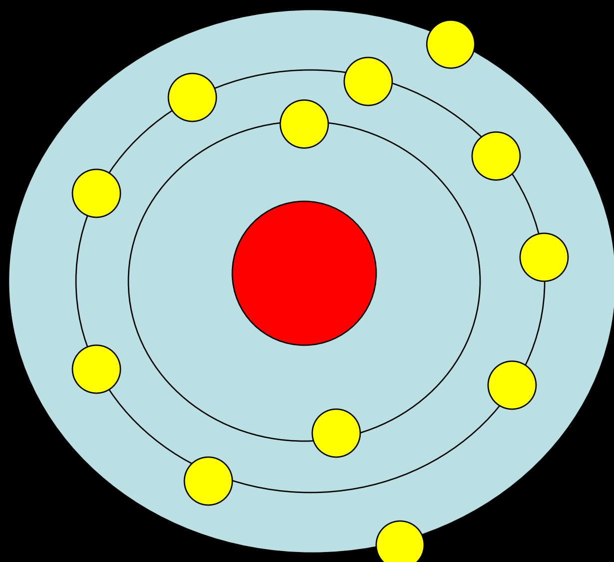


- **The atom will lose the valence electrons.**

- **Without any electrons, the energy level DISAPPEARS, and we are left with the full energy level directly below:**

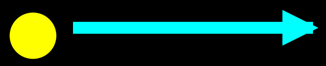
Satisfying the Valence


Electron

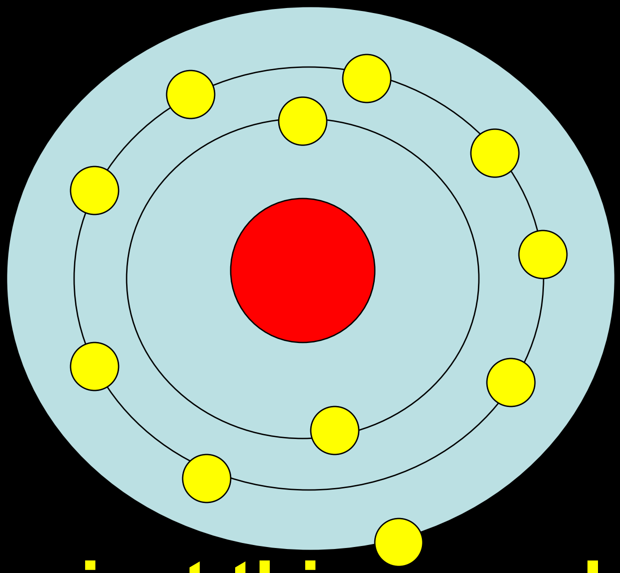


The easiest thing would be for the atom to LOSE those two outer valence electrons. Without any electrons, the energy level DISAPPEARS, and we are left with the full energy level directly below:

Satisfying the Valence



Electron



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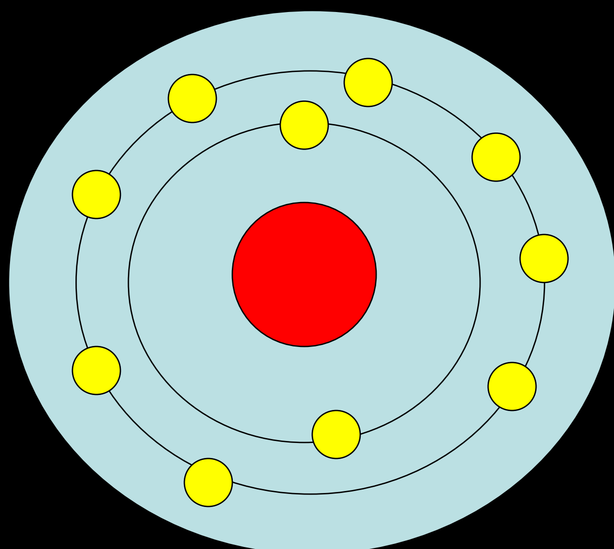
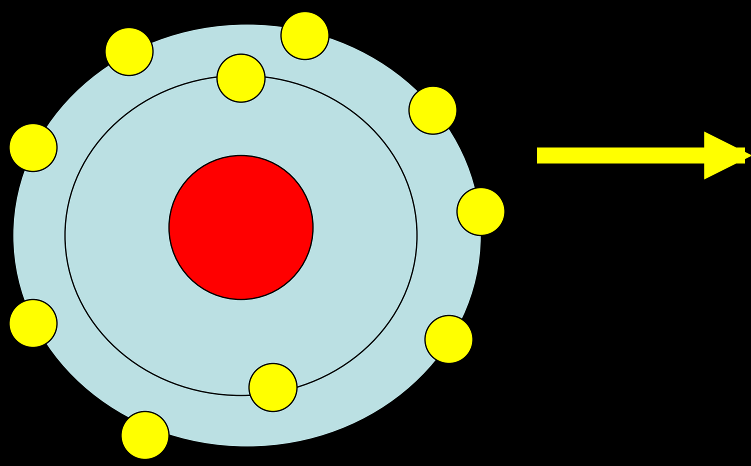
Satisfying the Valence


Electron



The easiest thing would be for the atom to LOSE those two outer valence electrons. Without any electrons, the energy level DISAPPEARS, and we are left with the full energy level directly below:

Satisfying the Valence



We are now left with a FULL outermost energy level and the atom is happy!

The easiest thing would be for the atom to LOSE those two outer valence electrons. Without any electrons, the energy level DISAPPEARS, and we are left with the full energy level directly below:

Writing Ion Names

- Ions are atoms that have either LOST or gained electrons to have a full outer energy level.→ no longer neutral.
- Ions are either positive (lost electrons) or negative (have gained electrons)

Everything starts out NEUTRAL

EX: Lost electrons to make outer energy level disappear: Li^{+}, Na^{+} Be^{2+}, Ca^{2+}

Ex: Gained electrons to make outer energy level filled: F^{-}, Cl^{-}, O^{2-}

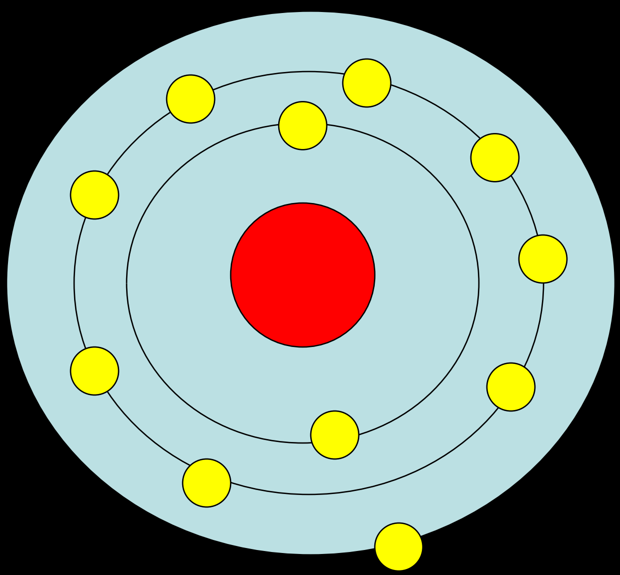
Ion Groups

- Ions (atom with a charge) that are negative (more electrons than protons) are called **anions**.

- Ions that are positive (more protons than electrons) are called **cations**.

Writing Ion Names

- Ions are atoms that have either LOST or gained electrons to have a full outer energy level.→ no longer neutral.
- Ions are either positive (lost electrons) or negative (have gained electrons)



Sodium Atom = Na

Writing Ion Names

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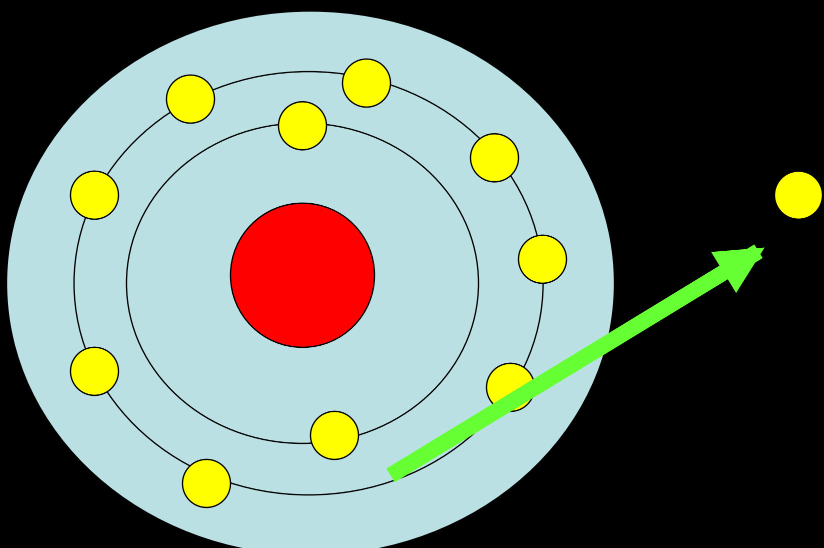

Electron is lost, so the Sodium atom Na has a net POSITIVE charge.

Ion written as Na^+

Writing Ion Names

- Ions are atoms that have either LOST or gained electrons to have a full outer energy level.→ no longer neutral.
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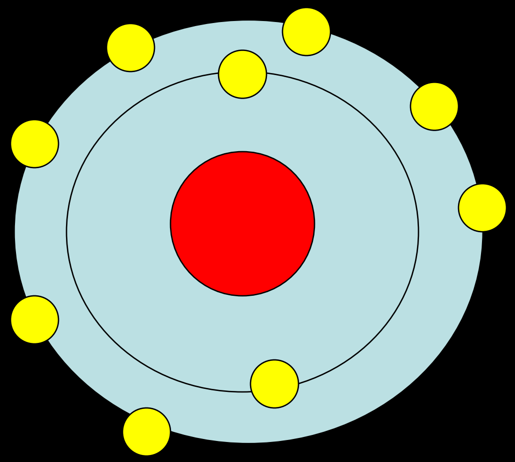
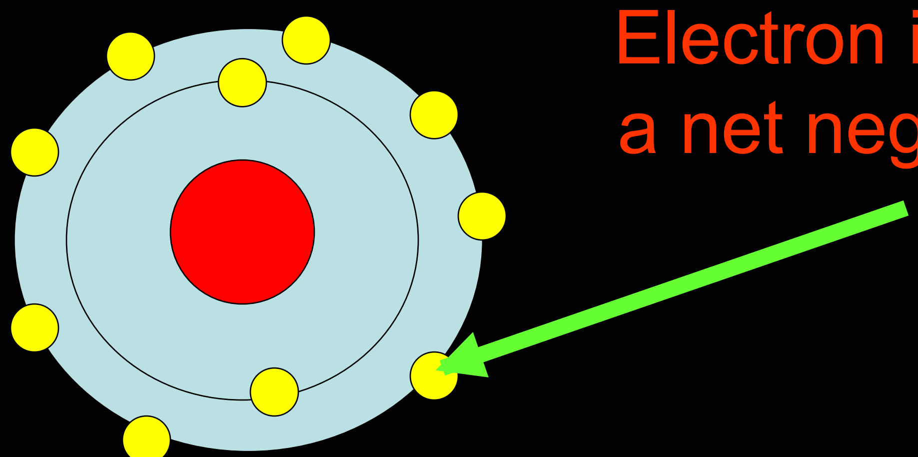


Fluorine Atom = F

Writing Ion Names

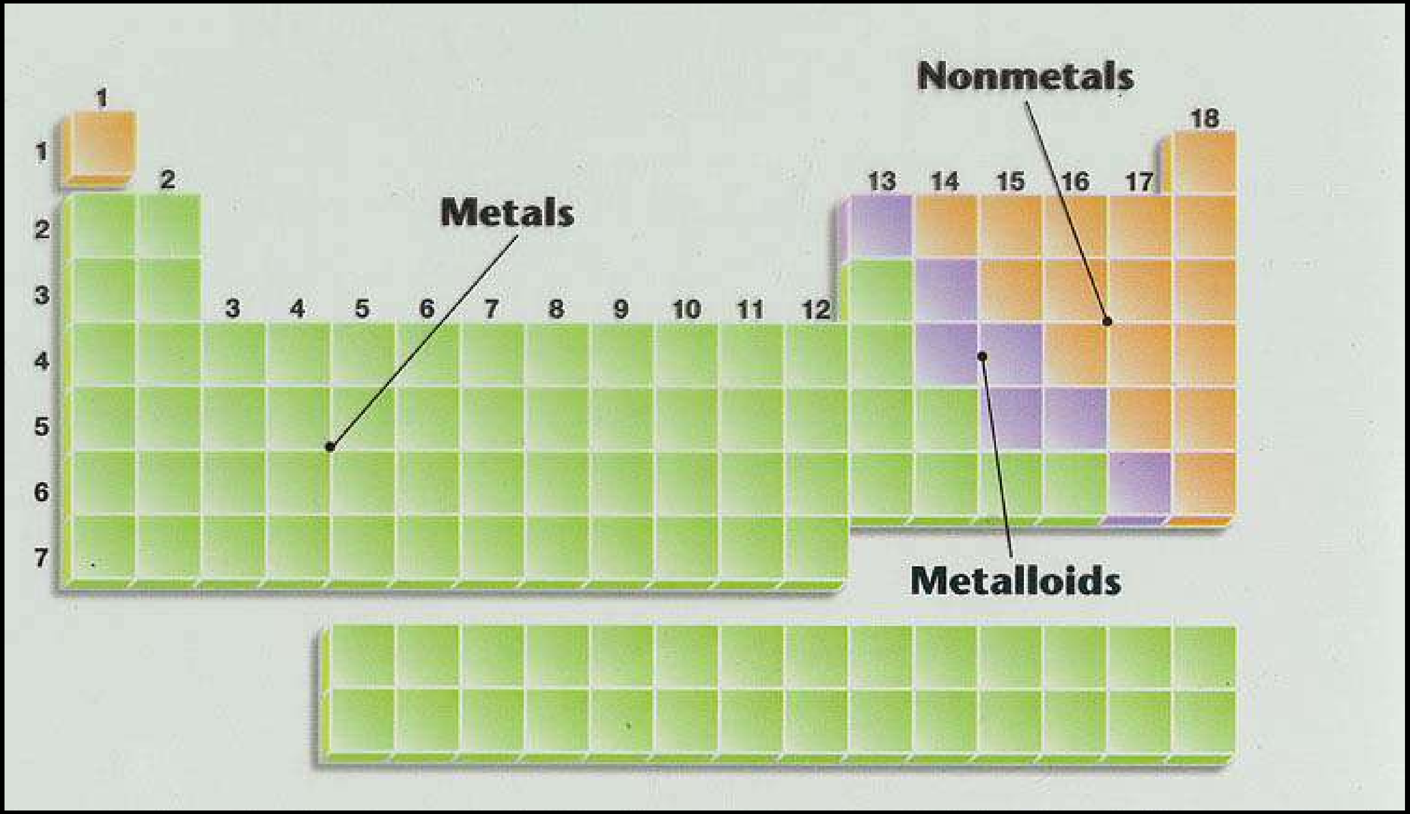
- Ions are atoms that have either LOST or gained electrons to have a full outer energy level.→ no longer neutral.
- Ions are either positive (lost electrons) or negative (have gained electrons)

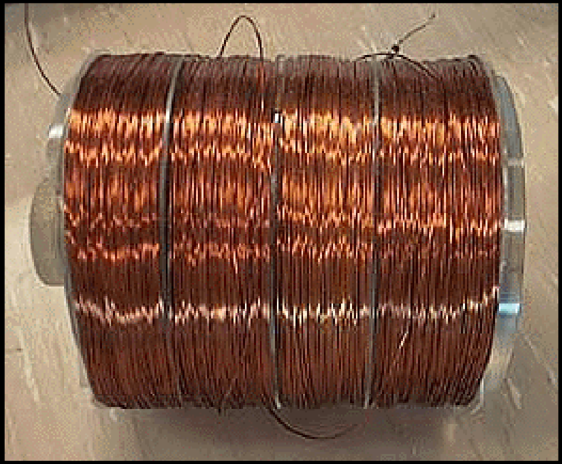


Electron is gained giving a net negative charge of F^-

Three General Categories

- Elements are classified as metals (left), nonmetals (right), and metalloids (semiconductors) (middle).

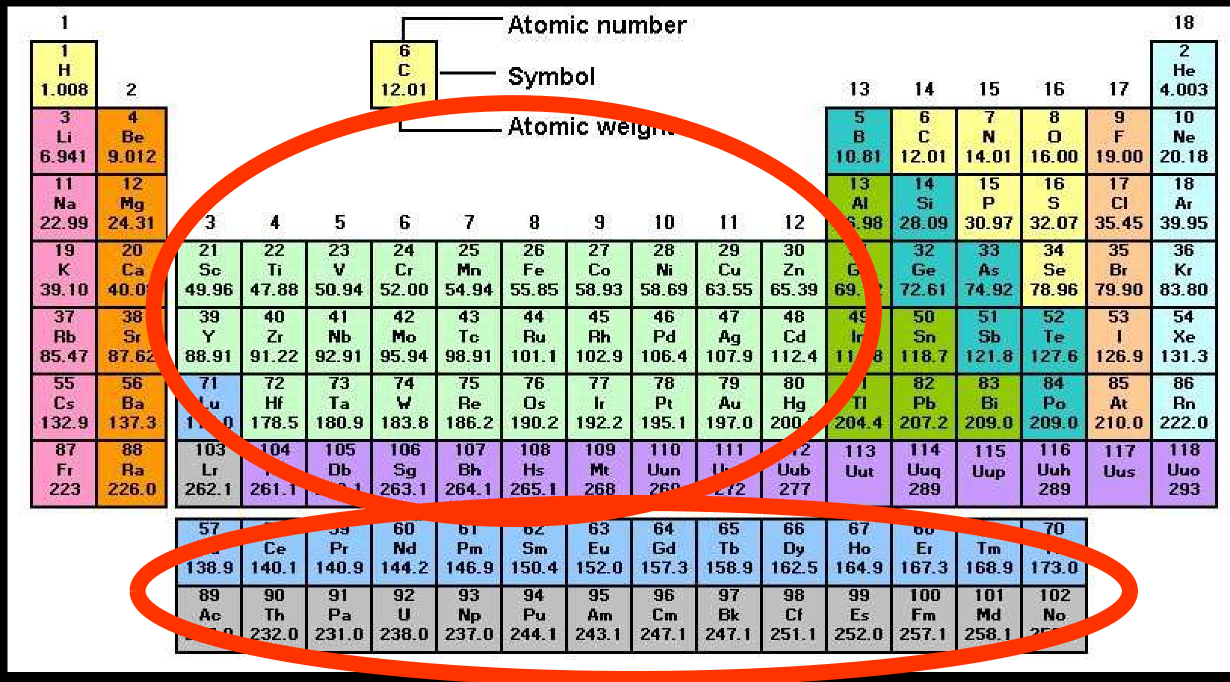




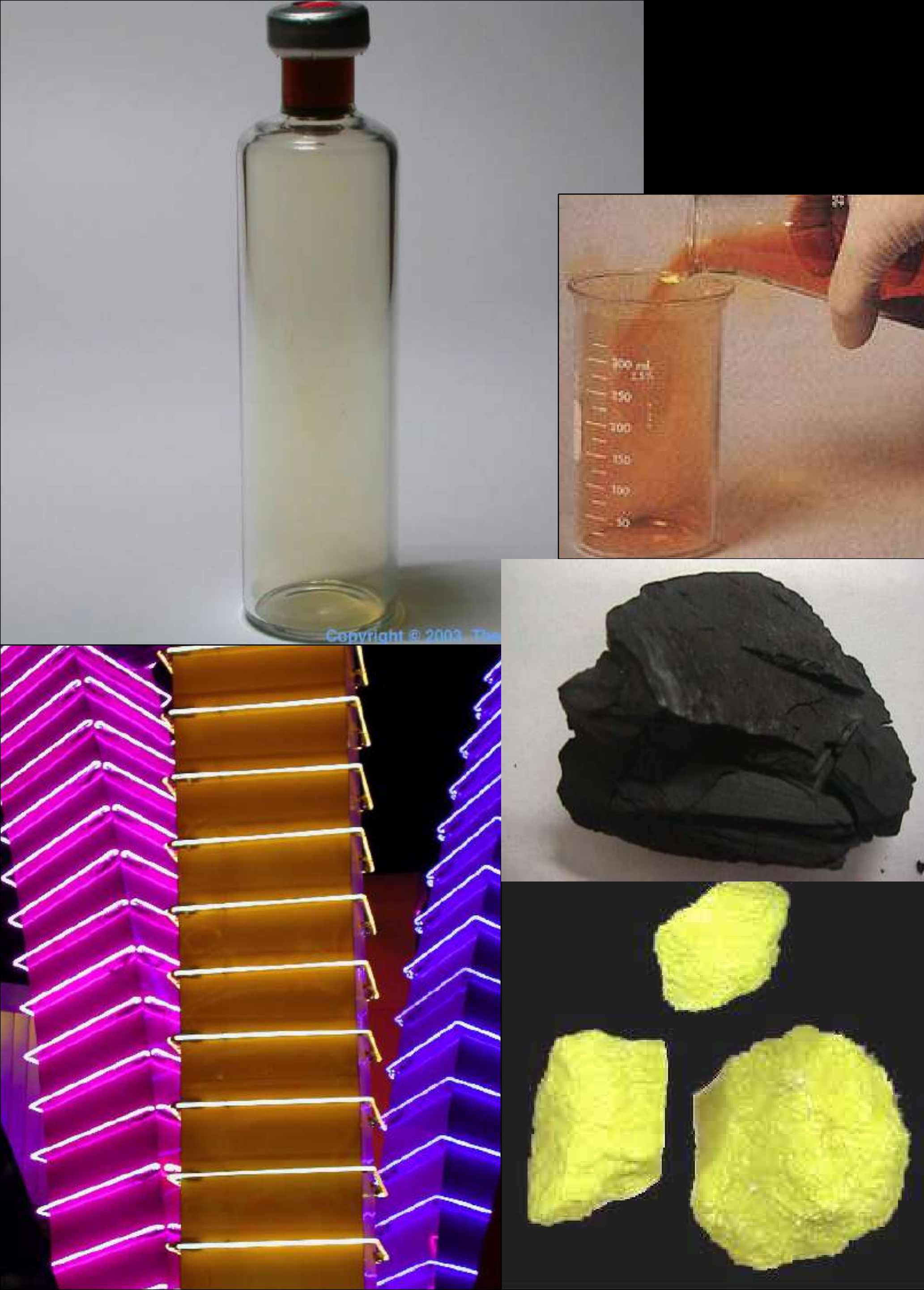
METALS

- Metals are good conductors of electrical current and heat.
- Except for mercury, metals are solid at room temperature.
- Most metals are malleable (able to be hammered without breaking.)
- Most metals are ductile (can be pulled into a wire).

TRANSITION METALS



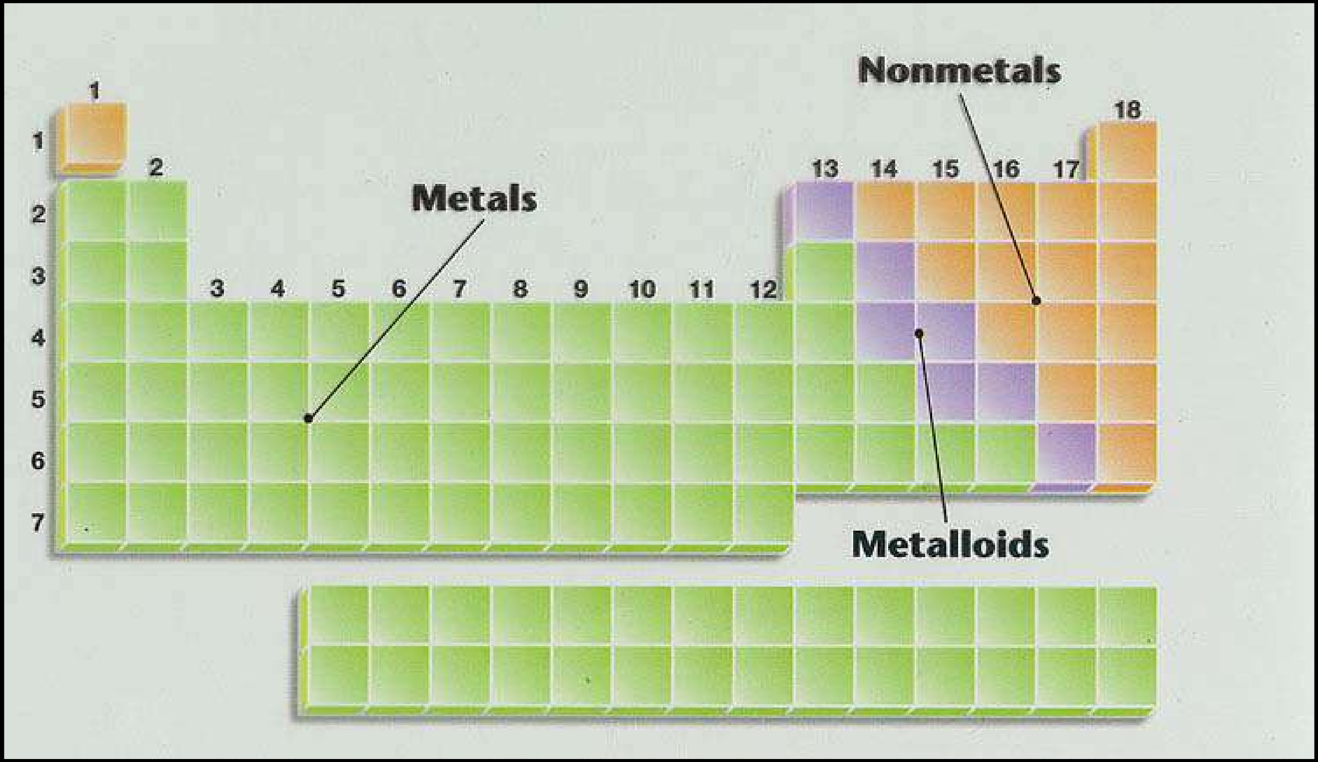
- **Transition metals** are elements that form a bridge between the elements on the left and right sides of the table (Groups 3-12)
  - Since Transition Metals do not follow the rule of electrons in outer energy level matching with the group number, we will not be dealing much with these.



NONMETALS

- **<u>Poor conductors</u> of heat and electric current (insulators).**
- **Many have <u>LOW BOILING POINTS</u> (gases at room temperature).**

METALLOIDS or SEMICONDUCTORS



- **<u>Metalloids or Semiconductors</u>** are elements that fall between those of metals and nonmetals (have characteristics of both metals and nonmetals)

Very Important Semiconductor

Silicon (has 4 valence electrons and typically found combined with oxygen in nature)

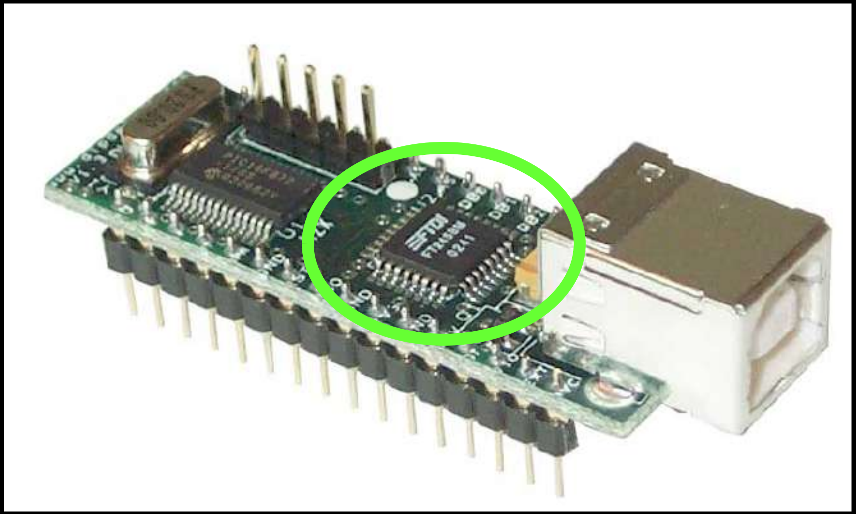
• Has a very high melting point (doesn't melt easily) like a nonmetal.

• Can conduct electricity like a metal.

Very Important Semiconductor

Silicon (has 4 valence electrons and typically found combined with oxygen in nature)

• Silicon is used in making microchips which need to withstand high heat in a computer but still able to transmit electrical current…more about this later!



Periodic Trends

- Elements become more metallic towards the LEFT and more nonmetallic towards the RIGHT on the periodic table
- The most reactive metals are on the **FAR LEFT**, and the more reactive nonmetals are **ALMOST TO THE FAR RIGHT**.
- The group (column) to the **FAR RIGHT** is **THE MOST NONREACTIVE**!